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ABSTRACT

The first working paper of the Learning in Science Project, "An Initial Framework," outlined what was then seen as the major aims of the project and suggested how these aims might be achieved by three phases of research: exploratory (to observe teaching/learning in Form 1 to 4 science classrooms and to identify difficulties perceived by various individuals); in-depth (focusing on teaching/learning of selected aspects of science); and action-research (exploring ways of overcoming difficulties/problems identified in the first two phases). Presented in this document is a reconsideration of the initial framework, reviewing major accomplishments of the completed first phase and specifying more clearly plans for the in-depth phase and its relationship to the proposed action-research. Comments obtained during first phase structured/unstructured interviews (from students and school personnel) and observations by project staff have provided three distinct albeit related, investigatory probes of the in-depth phase: (1) children's science; (2) children's classroom experiences; and (3) children's outlook on science. Each of these aspects of the in-depth phase is discussed and the various types of issues to be explored are considered. The action-research phase will be concerned with developing strategies built on the knowledge gained from the examination of these three areas. (JN)

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LEARNING IN SCIENCE PROJECT

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RECONSIDERING THE FRAMEWORK

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WORKING PAPER No. 14

RECONSIDERING THE FRAMEWORK

A WORKING PAPER OF THE LEARNING IN SCIENCE PROJECT

Roger Osborne, Peter Freyberg, Ross Tasker, Keith Stead

April 1980

Introduction

The first working paper of the Learning in Science Project, "An initial framework", produced in March 1979, outlined what was then seen as the major aims of the Learning in Science Project and suggested how these aims might be achieved. One of the major decisions made at that time was to envisage the Project as involving three phases of research: an exploratory phase to observe the teaching and learning of Form 1 - 4 Science in classrooms and to identify difficulties as perceived by a variety of people; an in-depth phase to focus on the teaching and learning of selected aspects of science at this level. and an action-research phase based on the findings of the first two phases.

Now, at the commencement of the in-depth phase, it seems desirable to reconsider the initial framework, to re-affirm or modify the decisions made a year ago and to specify more clearly at this stage in the project our plans for the in-depth phase and its relationship to the proposed action research.

We wish to say at the outset that our reconsideration of what has been achieved in the initial phase of the project has confirmed our views on the basic philosophy, the broad goals, and the methods which we initially envisaged for the project. In particular we would wish to reaffirm the emphasis of the project on (i) the 'actual' and 'student' curriculum, (ii) the learner as the initial focus of study and (iii) the need for the project outcomes to be of relevance and use to the classroom teacher.

The exploratory phase

Investigations during the exploratory phase followed closely both the intention and the timetable as detailed in the initial framework. As outlined by Tasker et al (1980) much of the data collected in the exploratory phase came from recorded interviews, and observations, of teachers and pupils. Additional information was also gathered in recorded interviews with others associated with Form 1-4 Science, namely inspectors, science advisers, ex-pupils and so on. A major concern was to maintain high context validity and to this end considerable attention was given to the way interviews were set

up and access to the classroom gained. It is envisaged that, in the final stages of the project, papers outlining the strategies adopted to gain access to classrooms, and also to gain information in classrooms and in interviews with pupils, will be produced both for other researchers and for teachers. In retrospect an important aspect of the exploratory phase was the establishment of a colleague relationship between members of the project team and teachers in the area. This provided teachers with the confidence to readily invite us into their classrooms and to allow us to work freely with their pupils. All interviews and classroom proceedings were recorded on audiotape, transcribed and then each transcript searched for possible significant statements. These key statements were annotated on the transcript and categories of information established and the specific issues ordered within these categories. New categories emerged whenever a comment or observation could not be placed in an existing category. Early transcription and categorization of the material acquired was found to be essential, since it was then possible to explore issues as the data gathering proceeded and thereby isolate idiosyncratic comment from that of wider concern.

Relatively quickly the need to generate new categories was diminished and gradually comments, and associated observations in classrooms tended to support views already expressed or perceived rather than to add a fresh perspective. Figure 1 details the categories grouped under national issues, local issues, and classroom issues related to teaching and learning. Most of the teaching and learning categories were further divided into three components;[1] comments related to teaching by teachers, pupils, and others; comments related to learning by these same groups of people; and thirdly specific examples of the problems and difficulties which had been commented on, as recorded by our own classroom observers. Attempts to isolate particular problems and difficulties from the categorized data were soon abandoned as a great many specific problems and difficulties were found to be interrelated. Eventually, eleven broad aspects of Form 1-4 Science which seemed to usefully organize the information available, emerged as meaningful foci. These foci and the stronger link each had to the various categories established are indicated in Figure 1.

Comments and observations relating to these various foci were collated in a set of discussion papers, known as the FOCUS Papers (Working Papers 2-12).[2]

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[1] Denoted by a (3) after the category name

[2] These Papers, along with Working Papers No. 1 and 13, form Freyberg et al (1979)

As well as serving to describe problems and difficulties in Form 1-4 Science the focus papers were written in a way which it was hoped would open up the problem issues to a wider audience than those involved in the project team. A selection of readers was asked to feedback to the project their thoughts about the focus issues in terms of a number of specific questions. In this way the papers were seen as a way to test the validity of our findings and a way of involving the audience of the project's ultimate outcomes in decision making relating to the in-depth phase of the project. In practice it has been found necessary to actively seek out comment from individuals and groups of people, rather than to rely on spontaneous feedback.

Up to the present time most comments that have been received tend to elaborate issues rather than raise new aspects or challenge statements made. There has been no really contradictory comment and in general readers have tended to be supportive, agreeing that the issues raised are the issues they also see as valid and important. In the light of these comments, and from our own thinking on these issues together with the guidance of our advisory committee, decisions have been made in relation to the in-depth phase of the project.

The in-depth phase

In the 'initial framework' it was stated "the in-depth phase will focus on the teaching and learning of selected aspects of the science course. It is expected that selection will be based mainly on the findings of the exploratory phase and that emphasis will be placed on student development of concepts, skills and attitudes relevant to selected aspects."

In the exploratory phase a wide variety of issues related to Form 1-4 Science have been explored. Many of the issues raised were not seen as appropriate or profitable for further investigation within the Learning in Science Project. For example the resolution of some issues require extensive comparative surveys for which we do not have the resources. Increasingly it has become clear to us that the project could best concentrate on the problems of learning science and then, and from that perspective, approach the problems of teaching science. The focus papers, EXPERIMENTS, LEARNER, KNOWLEDGE, PROCESS SKILLS and ATTITUDES in particular, focus on issues which are seen as of central concern to the Learning in Science Project. Our readers reaction to these papers have reinforced our view that the learner should be our first concern.

As to our initial intention to place emphasis on the development of student knowledge skills and attitudes relative to selected aspects of teaching and learning science, the work of the exploratory phase has not only enabled us to gauge the importance of these issues but also to clarify more clearly three identifiable and related aspects of Form 1-4 Science in which they are imbedded. These three aspects which we will label CHILDREN'S SCIENCE, CHILDREN'S CLASSROOM

EXPERIENCES and CHILDREN'S OUTLOOK ON SCIENCE provide the three distinct but related investigatory probes of the in-depth phase (Figure 2). Each of these aspects of the in-depth phase will be considered in turn.

Children's science

Science is concerned with how and why things behave as they do. However scientific knowledge involves not only ideas about such events, but also a meaningful language whereby these ideas may be communicated to others. From our work in the exploratory phase of the Project it is clear to us that children do acquire some sort of coherent view of the world based on their experiences, but not surprisingly these views are not necessarily consistent with those of the scientist. Also, children do have meanings for many words used in science, but again those meanings may be quite different from those of scientists using the word in a scientific way. For example, an animal is for many children a four-footed mammal, whereas the scientist uses the term with much wider reference. By children's science we mean the views of the world and the meanings for words that children do have and bring with them to science lessons. We would argue that the more we know about children's views and language the more we will be able to provide learning experiences for them as pupils whereby their ideas can be modified and developed; so that they can interpret events and words from a more scientific perspective or, where this is beyond them, at least appreciate aspects of the scientific perspective.

If one aspect of the in-depth phase is to investigate children's science then we have to consider how this might be done. In an earlier working paper (No. 3) the interview about instances method (I.A.I.) [Osborne and Gilbert, 1979] was used to investigate students meanings for the word 'force'. We have now developed a second but similar, type of interview, called interview-about-events (I.A.E.) which is used to explore various aspects of students' views of the world. In this latter type of interview, a particular set of events, e.g. water boiling, condensing, ice melting and so on are demonstrated to the interviewee. The child is asked to describe what (s)he sees happening and then asked to explain, in his or her view, what has happened. Having gained insight into the child's view of the event, the interviewer then investigates what knowledge the child has of the scientist's view and how this relates to the child's ideas. As detailed in Figure 3, both I.A.I. and I.A.E. can therefore be considered to involve three phases, and both can be extended to a fourth phase which explores in terms of the background of the particular interview, the child's outlook in science. To illustrate the I.A.E. method, the set of events used in a study of physical change are given in Figure 4. In Appendix I extracts from interviews exemplify the type of information which can be obtained in the final two phases of such an interview.

It is now necessary to consider what aspects of children's science should

be considered in the in-depth phase. If children's science and scientist's science are concerned about things and about how and why they behave as they do, then it would seem sensible that science teaching for most of the school population should first be concerned about the familiar world in which the child works and lives. One might categorize both children's science and scientists' science into three areas:

(a) things that cause other things to happen, for example "why do I slip when I walk on icy surfaces?"

(b) things that sometimes turn into other things, for example "why do shiny nails sometimes turn into rusty nails?"

(c) things that live and die, for example "what are spiders and where and how do they live?"

From the work of the exploratory phase, from the collating of comments from a variety of people on particular concepts and topics, from meetings with specialist and interested groups to focus down on particular concept areas, and finally, with consideration of the extent and nature of the manpower available to the Learning in Science Project, a series of investigations has been planned for the in-depth phase. The words, and events to be investigated, the insights into children's science which it is hoped might be evoked, and the particular aspects of scientists' science which are related to these studies are detailed in Figure 5.[3]

A variety of outcomes of this work on children's science is envisaged. Firstly, with respect to particular science topics a clearer appreciation of children's language and views of the world should be established. In terms of the action research phase of the project such knowledge will provide a firm basis on which to design teaching strategies which will not only challenge individual pupil viewpoints but will provide experiences whereby these viewpoints can be replaced or modified.

Secondly we have already observed aspects of children's science which are common to a wide variety of concepts and viewpoints. Children have egocentric and anthropocentric views; they tend to resort to anthropomorphism and animism; they tend to dismiss things they cannot observe as not existing, they tend to reify some abstract ideas, e.g. force, momentum, and there is confusion between the specialist and everyday meanings for many words. In addition, as students gain an understanding of the scientists' view of the world they sometimes get basic scientific concepts confused, e.g. confuse electrical energy and electric

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[3] It is anticipated that younger children will have little or no understanding of the scientists' view while for some older children the distinction between their views and the scientists' views will be indistinguishable.

current, they gain superficial knowledge with little or no real underlying understanding, and they acquire and retain in their knowledge store quite contradictory views, [Osborne and Gilbert, 1980]. Such generalized findings across concepts may well help us to suggest types of lessons which may overcome some of the blocks which seem to prevent children from reaching a more scientifically-coherent viewpoint.

Children's Classroom Experiences

The classroom is but one of many areas of experience that contribute to the various views of the world 11-14 year olds hold. Nevertheless, in terms of helping to shape particular aspects of these views it can be a powerful influence. The classroom provides a series of 'episodes' (teaching and learning opportunities) orchestrated by the teacher. In Form 1-4 science classrooms such episodes often take the form of investigations or experiments which are variously intended to involve pupils in activities requiring the use of scientific processes and habits; to lead pupils to outcomes of scientific significance; and to foster in pupils an interest in science in general.

Our work in the exploratory phase raised questions regarding the effectiveness, as a teaching and learning mechanism, of investigations and experiments (tasks) as currently practised in Form 1-4 science lessons. Of particular concern was comment and observations which frequently suggested a lack of correspondence between expected pupil outcomes, as indicated by teachers' and/or textbook writer's intentions for specific tasks, and actual pupil outcomes, achieved as a result of watching or carrying out such tasks. With so much teaching and learning of science at this level being centred on investigative and experimental tasks it became apparent that these classroom experiences required further study.

Of major importance is the strong contextual influences on most classroom tasks. Realisation of this led us to the decision that in-depth studies must be carried out in the natural setting i.e., in normally operating Form 1-4 science classrooms and lessons. The work is taking the form of a series of observations each supported, as appropriate, by gentle questioning. The observations are aimed at establishing four aspects in relation to any episode: what the actual task is; what the pupils actually do; what outcomes the pupils actually achieve; and what the significance of actual pupil outcomes are in terms of 'view of science' (i.e., pupils' science, teachers' science and scientists' science) and scientific skills and habits. The questions attempt to establish both pupil and teacher perceptions in respect of the above four aspects. The relationship of observations to both pupil and teacher perceptions is set out in Figure 6.

Teacher and pupil actions observed are recorded in notes made at the time of observation, while an audio-record of verbal interactions (teacher-class, teacher-pupil, pupil-pupil, pupil-observer and teacher-observer) is made on audio-tape. Other methods (video-taping and polaroid photography) for noting observations have been considered but concern over disruptive effects on normal class proceedings has so far excluded their use.

As soon as is possible after observation of an episode, the audio-recording is transcribed and annotated, as required, from the notes made during the observation (Figure 7 contains extracts from an annotated transcript to illustrate the type of record obtained). The annotated transcript is then searched for, actions and comments of possible significance, and identifiable issues are then categorized in the manner used in the exploratory phase of the project (see p 2). The process of analysis, confirmatory search, and re-analysis is regarded as complete when all further observations of key events and statements can be fitted into existing categories, rather than requiring the establishment of new categories, and also by the clarity of descriptions of the categories themselves.

At this stage of the work only the nature of the outcomes rather than the actual outcomes which will develop out of the described analysis are predictable. It is envisaged that intensive study of science classroom episodes will provide insights into the nature and extent of mis-matching of pupil actions, perceptions and outcomes, with teacher intentions and perceptions. In addition, it is hoped, that those task characteristics which influence pupil outcomes will be identified and that the nature of such influence can be described - for example, the nature and role of links between specific process skills and scientific habits and the outcomes which pupils achieve. Such information, when obtained, will provide the basis for the Action-research phase of the Project, as well as being of direct interest to science developers and science teachers.

Children's outlook on science

An important aspect of any science course is children's outlook on their science studies. This relates not only to children's motivation and enjoyment but also to their desire to pursue the study of science beyond the fourth form. Our observations and literature search in the exploratory phase of the project have identified two general areas of concern. First, there are considerable differences in the numbers of girls and boys who continue their study of science subjects (particularly the physical sciences) beyond the fourth form. Secondly, it has been observed that the majority of Maori and Polynesian students soon turn away from science. The differences in outlook on science of these groups, and the associated affective, linguistic, cultural and sociological influences which may be causing them, is providing the focus of study for the third and final area being investigated in the in-depth phase of the Project.

It is our present view that one of the important aspects of our work in this area is to learn, appreciate, understand and accept, the different value systems, expectations, thinking styles, learning preferences, perceptions and beliefs of the particular groups of learners identified above. The girls, or Maori students, who "fail" in science could have done so for a variety of reasons, of which lack of ability is only one. They could, for example, have rejected the academic criteria for 'success' long ago, not so much as being irrelevant but being simply non-relevant. The pupils who come from a background in which the learner is expected to rely primarily on his/her own eyes and not to question the instructor is disadvantaged when this particular role is denied them and they are expected to ask questions of their teachers in order to learn. The learners who are 'person' oriented rather than 'thing' oriented may well dislike science because it is perceived as lacking in social involvement! The pupils who habitually ascribe their academic success or failure as being completely beyond their control present a different kind of motivational problem to that of the students who take complete responsibility for their own progress. Similarly pupils who prefer to project their own organization on to the material presented to them may well feel restricted by demands to think in a prescribed way. They may prefer to respond affectively rather than analytically. Perceived scientific knowledge and methods of science may conflict with traditional beliefs or religious teachings and present the learners with a difficult decision with respect to retaining or rejecting family belief systems.

Furthermore, certain groups of students have particular problems with language in relation to science. Reference has already been made to the difficulties which arise when everyday words are used in the scientific sense. However, this kind of difficulty is increased for those pupils with a restricted vocabulary (as a consequence of it being part of a second language or of limited verbal experiences). Problems that arise include the free interchange of such words as the logical connectives "if" and "when"; the lack of familiarity with every day roots from Greek or Latin which enter into scientific vocabulary ("geo", "therm", "ante", "anti", and so on); a complete absence in the learner's language of necessary concepts (e.g. infinity, hypothesis) and particularly for some Island groups interference from non-decimal counting systems and the confusion of tenses and plurals.

In the in-depth phase of the project, therefore, work on children's outlook on science will attempt to explore the types of issues raised above, and, in so doing, will attempt to identify the nature, extent and relative importance of some of the variety of factors which influence the learner's affective response to his or her science. The exploratory phase revealed something of the range and complexity of the tangle of attitudinal and motivational factors involved (see Focus on Attitudes). To explore the development of particular value systems,

learning preferences, beliefs and expectations a systematic interviewing schedule across a fairly wide range of pupils, teachers and parents is being employed.[5] The interview approach also provides the flexibility to enable the interviewer to explore in depth the expressible reasons why learners and small groups of learners profess to like or dislike aspects of science. However it is also felt desirable to try and gain insight into the deeper, often implicit and often unrecognised, reasons for particular attitudes. For this reason attempts are being made to complement the interview work by information gained using a variety of alternative techniques. The potential of such techniques as the Repertory Grid (Fransella and Bannister, 1977) and various paper and pencil instruments are being explored at present.

The Action-research phase

This phase of the Learning in Science Project will be concerned with developing teaching strategies which build on the knowledge gained in the in-depth phase. Some indication of the kinds of contributions each in-depth aspect can make to this phase has already been given. However, in addition to establishing specific areas in Form 1-4 Science that can usefully become the focus of action-research, each will provide other valuable information. 'Children's science' will suggest directions for challenging specific viewpoints of children in ways which enhance the likelihood of the scientific viewpoint becoming established and integrated into pupils' cognitive structures or at least appreciated. 'Children's classroom experiences' and 'children's outlook on science' will suggest new practices likely to enhance modification of pupils concepts, skills and attitudes. These new practices may require a reconsideration of the relationship between learner and task as well as of learning objectives.

The jumping off point in our development of new curriculum strategies will be first to attempt to teach individual children whose views we have previously explored. Hopefully, some generally successful teaching strategies will be sorted out, which can then be tested with small groups of children before modification, development and appraisal in the classroom setting. In the final stage a range of teachers and classes will be involved.

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[5] As the cross-cultural differences in attitude and motivation are recognized as providing particular problems for the learning and teaching of science, several schools and communities with high Maori and Polynesian populations are involved in this work.

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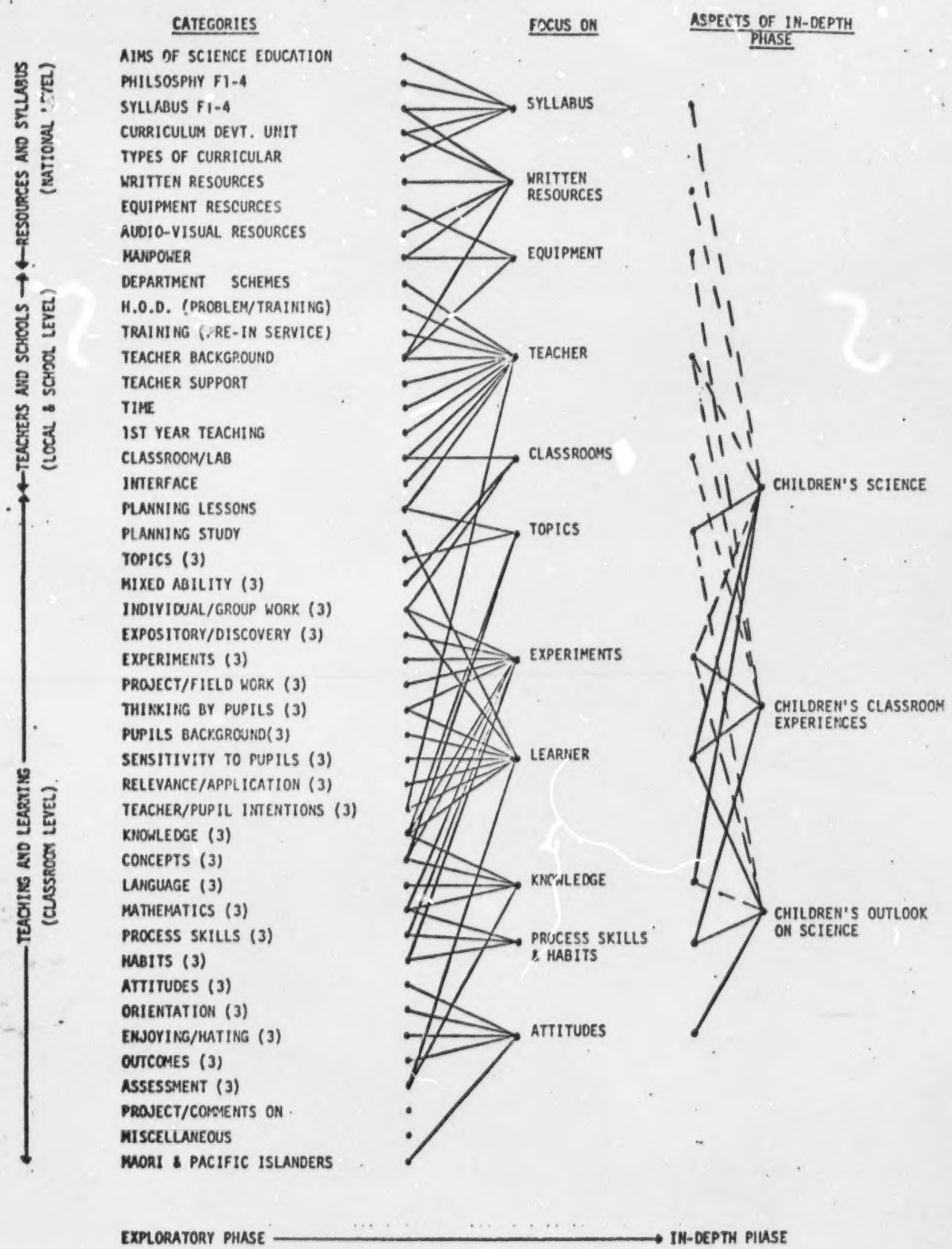
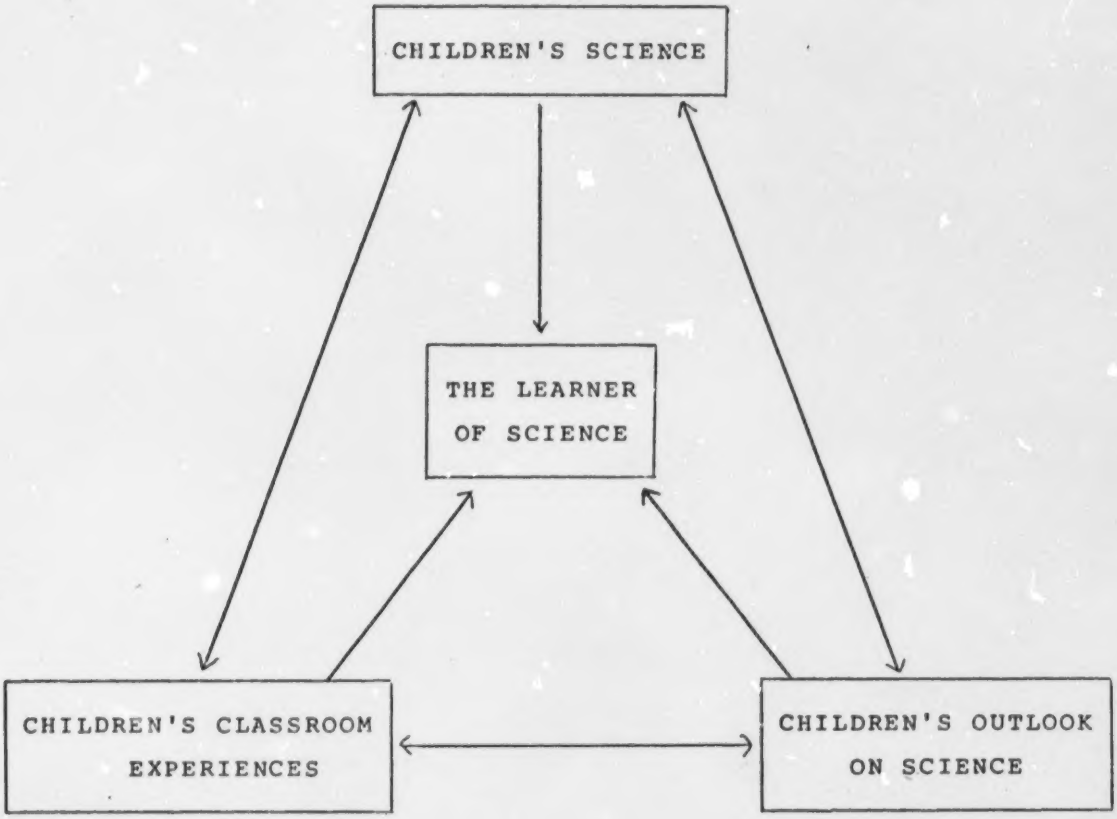


Figure 1: Categories and foci of the exploratory phase and the relationship of these to aspects of the in-depth phase.

probing children's minds in terms of their views of the world, and their meanings for the words they use.



probing children's experiences in the science classroom, particularly where children are doing science.

probing children's outlook on science, particularly the influence of various factors, e.g. affective, linguistic, cultural and sociological, on this outlook.

Figure 2: The three aspects of the in-depth phase of the learning in science project.

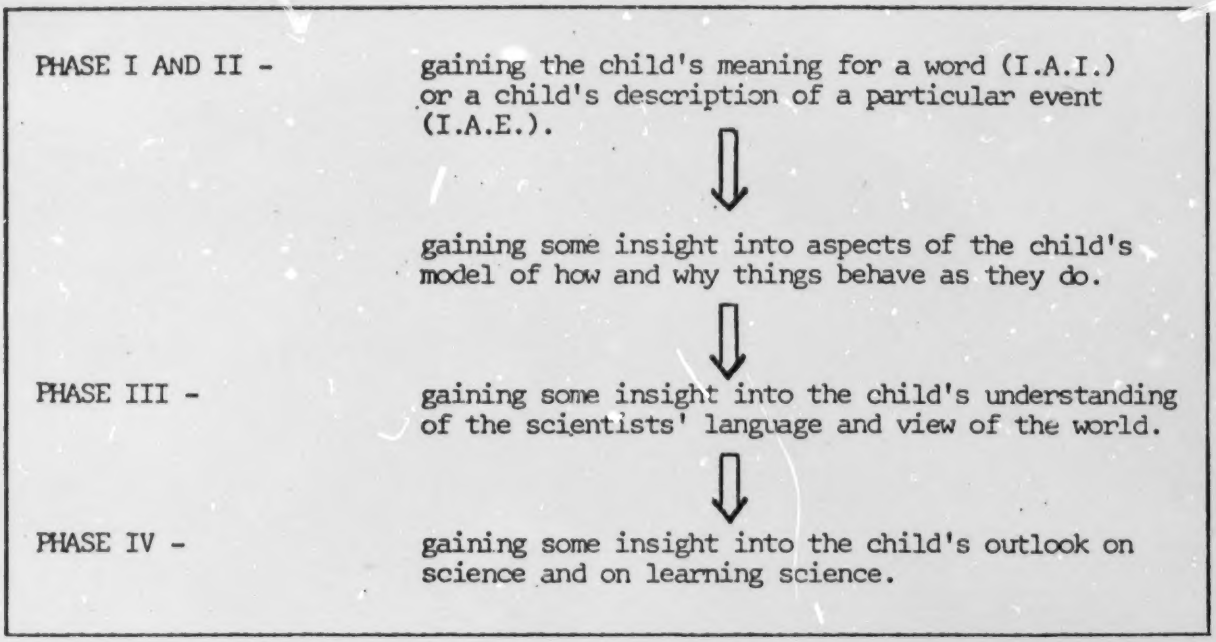

PHASE I AND II -
gaining the child's meaning for a word (I.A.I.) or a child's description of a particular event (I.A.E.).
gaining some insight into aspects of the child's model of how and why things behave as they do.
PHASE III -
gaining some insight into the child's understanding of the scientists' language and view of the world.
PHASE IV -
gaining some insight into the child's outlook on science and on learning science.

Figure 3: Both I.A.I. and I.A.E. can be considered a three, or even four, phase process.

Interview schedule

1. Water boiling in an electric jug.
2. Steam from the jug condensing on a plate.
3. Sugar dissolving in a cup of warm water.
4. Water evaporating from a warm plate.
5. Water condensing on the outside of a jar containing ice.
6. Ice melting.

Typical Questions e.g. on boiling

(i) where do the bubbles come from?
(ii) what are the bubbles made of?
(iii) where do the bubbles go to?
(iv) what is the steam made of?
(v) what is the water made of?

Figure 4: Exploring the child's view of physical change using the Interview-about-Events technique.

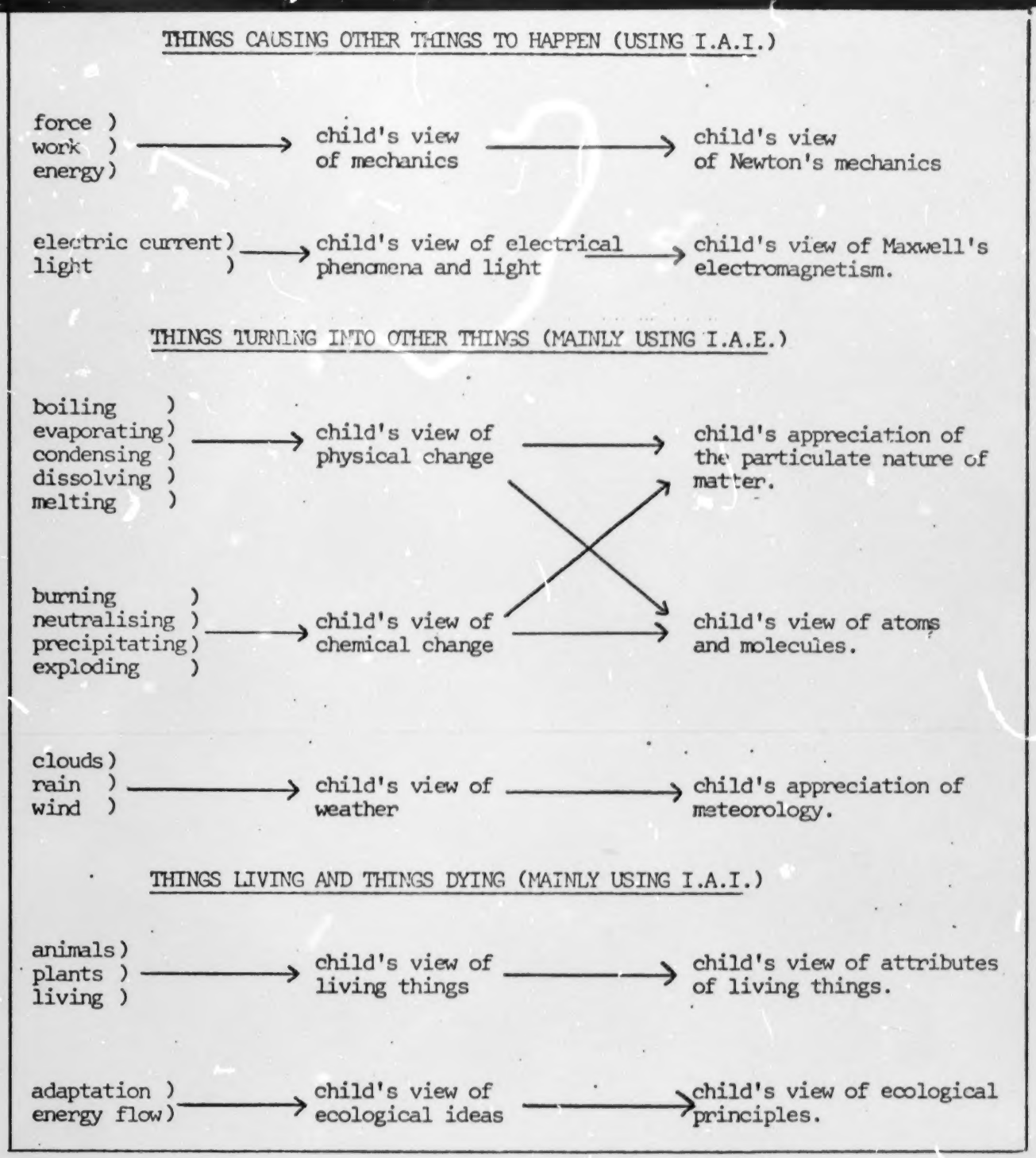


Figure 5: Aspects of science under investigation in the in-depth phase.

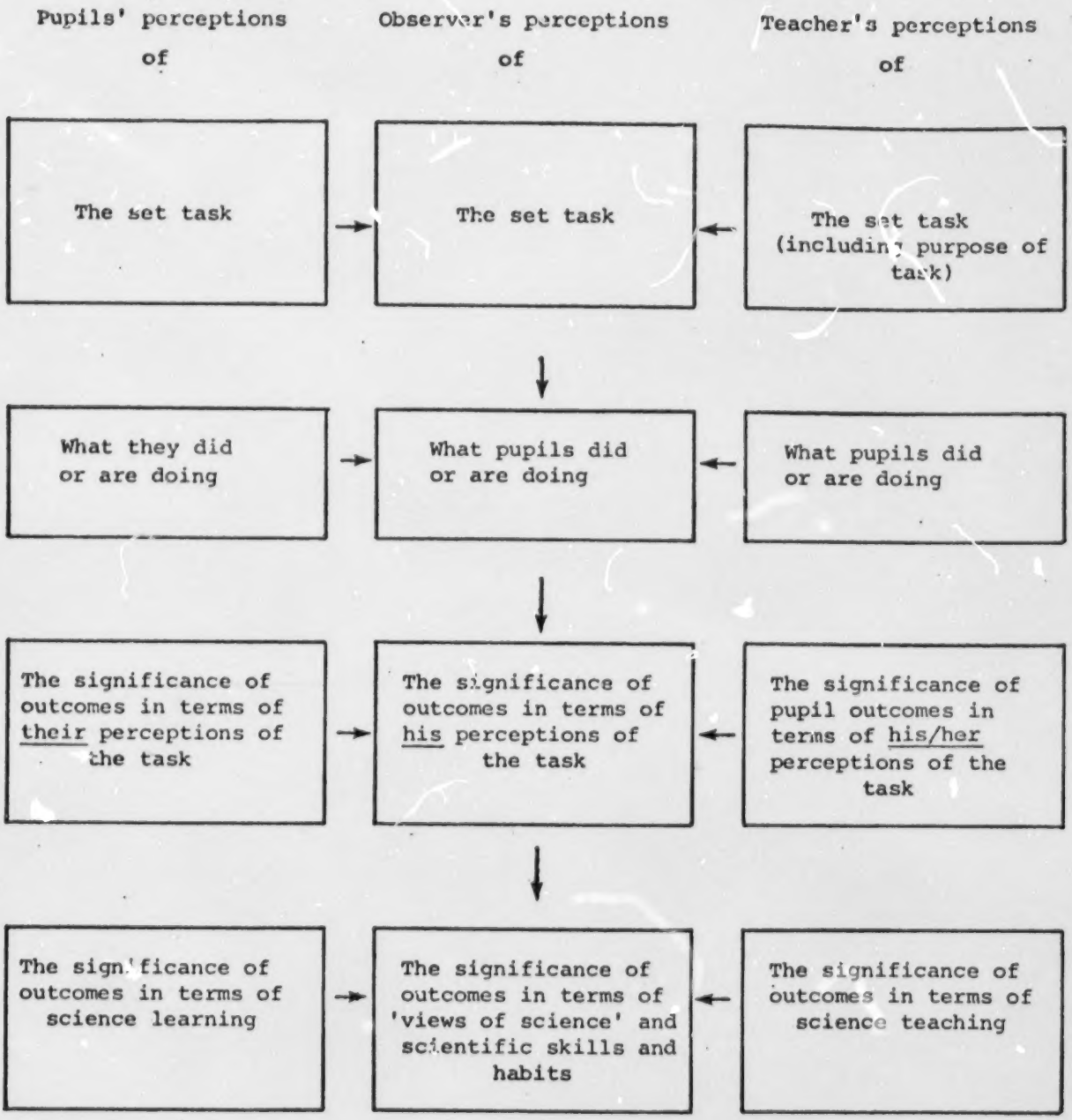

Pupils' perceptions of
Observer's perceptions of
Teacher's perceptions of
The set task
The set task
The set task (including purpose of task)
What they did or are doing
What pupils did or are doing
What pupils did or are doing
The significance of outcomes in terms of their perceptions of the task
The significance of outcomes in terms of his perceptions of the task
The significance of pupil outcomes in terms of his/her perceptions of the task
The significance of outcomes in terms of science learning
The significance of outcomes in terms of 'views of science' and scientific skills and habits
The significance of outcomes in terms of science teaching

Figure 6: Observing science classrooms.

The following conversation comes from a group of boys in a class of 13 year olds. They were instructed to half-fill three test-tubes - one with sugar solution, another with a starch solution and the third with water. To each of these was to be added a few drops of Benedict's solution (blue-green in colour) using an eye-dropper. Finally each solution was to be heated gently and any changes noted.

The observations [in brackets] are from notes made as they carried out the task.

P1 Did you wash it out?

P2 Yeah, I washed these [test-tubes].

P1 Did you wash the dropper?

P2 Yeah, I will.

P1 Shall I change this [test-tube] because it's got little bits of iodine in it? [P2 had not washed away completely the materials used in the previous task].

P3 It'll be all right.

P2 This is the sugar [adding Benedict's solution to the sugar solution by immersing the eye-dropper in the sugar solution, then squeezing the bulb].

P1 Can I hold it [over the bunsen flame]?

P3 If you turn it on its side it heats up quicker - get the flame like that [tilting the test-tube and lowering it to sit just above the top of the bunsen barrel].

P1 We don't want the glass melting [shifting the test-tube up into the hottest part of the flame!].

P2 Hey, it's going - look at the colour.

P1 Yellow.

[P2 adds Benedict's solution to the test-tube containing the starch. He uses the same eye-dropper without rinsing it and the same 'immersion' technique, then holds the test-tube in the bunsen flame].

P2 It's gone a light green.

P1 A yellow-green colour.

[P2 repeats the procedure in exactly the same way with the water sample].

P2 What colour? Yellow ... It's kind of orange.

P3 They're all the same now.

[At this point the teacher interrupts the class - she states that people must be getting their solutions mixed up because groups she has observed are getting the wrong results. She tells them to repeat the work].

P3 Why are our tests all wrong? We didn't get ours mixed up.

P2 That's what she said.

P3 I bet you they were right.

P1 I dunno what we did wrong.

Figure 7: Part of an annotated transcript obtained from observation in the classroom.

DEAN'S VIEW OF PHYSICAL CHANGE HAVE BEEN EXPLORED USING THE INTERVIEW-ABOUT-EVENTS DETAILED IN TABLE 2. HE HAS THE IDEA THAT AIR AND WATER CONSIST MAINLY OF OXYGEN AND HYDROGEN AND THAT WATER CHANGES INTO AIR ON EVAPORATION. THE FOLLOWING IS AN EXTRACT FROM PHASE III OF THE INTERVIEW.

I. In written work on chemical equations and things, have you written H_2O? (Yes) Now what does that mean to you? Does that fit into anything we have been talking about this morning?

D. Yes, well the H is hydrogen ... it is a symbol ... splitting up the substance of air into the main things ... the hydrogen which is your H and the oxygen which is your O.

I. And what is the H_2, does that (the 2) mean anything to you?

D. The H_2 ... well if I hadn't been taught Science or Chemistry, I wouldn't be able to have a clue but from what I have been taught ... I might be wrong, but the way I have seen it, and the teachers have been trying to teach me ... that is the two is representing say that the hydrogen always goes around in two parts but it has got to have both parts to be called hydrogen ...(and the oxygen?) It exists as sort of one whole thing ... but whatever the hydrogen is made up of (it)is sort of split into two different sections.

I. O.K. what about other things like nitrogen?

D. That's by itself too.

I. Have you ever heard of Carbon dioxide? (Yes) How would you write that?

D. CO ... now hold on ... yes ... CO_2.

I. CO_2 now the 2 there does that mean anything to you?

D. Um, the only thing I could say ... I wouldn't say oxygen is split into two things ... you still have your carbon acting as an individual ... and the oxygen acting as an individual but because they have been put together you get this little 2 which is sort of a mixture of both carbon and oxygen ... that is like the linking up ... here is carbon ... here is oxygen (points to the air) and when you bang them together you get CO_2 because the 2 is sort of the thing that keeps them together.

LATER THE INTERVIEWER HAS FINISHED THE FIRST THREE PHASES OF THE INTERVIEW. SOME VERY CONFUSED IDEAS ABOUT CHEMISTRY HAVE BEEN UNEARTHED. THE FOLLOWING EXTRACT IS FROM THE FOURTH AND FINAL PHASE OF THE INTERVIEW.

I. Did you do much Chemistry in the 3rd and 4th form?

P. We did quite a bit ... we did quite a bit of writing chemical equations ... it took me ages to pick it up as I found it quite confusing ... as I know from lots of people, that at my age it is ... but after a while I started to understand it ... how to write some things ... and how some things got like that ... but (having been) taught be a teacher one way (I tend to) relate it in the same way but in my own words and my own thinking ... in an exam I would probably get it wrong but I could still think of it that way ... ... (You see,) when we are told to swot for a test we have got to swot in our book all the stuff the teacher's way ... we go home and we (try to) learn that, but as soon as it hits our eyes it goes in our brain (and) it goes the other way ... and (so) when we come to write it down and we think ... and write it down all our way - because of course it still means the same thing, there is no difference - but to the teacher there is a distinct difference between our way and (the teacher's) way ... and (the teacher's) way is the right way ... that's what I find hard ... ... if I could say how a teacher could instruct the class I would say he teaches the theory his way and says right ... and gets every kid in the class to write down their way of seeing that ... not what he has written but their way and puts it all together and tries to get a happy compromise and if there is absolutely no comparison try something else ... if there is then try and work on the kids' way ... and use the kids' ideas but every so often relate it back to his way ... just so they can see the relationship ... that's how I would like to see it done.

Appendix I: The type of information obtained from the last two phases of an interview-about-events.